Clinical consequences of periprosthetic leak after endovascular repair of abdominal aortic aneurysm

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Purpose: **The study was conducted to evaluate risk factors, natural history, and clinical consequences of a periprosthetic leak after endovascular repair of an abdominal aortic aneurysm.**
Methods: **We reviewed the initial and follow-up data, including angiograms, contrast-enhanced computed tomography (CT) scans, abdominal duplex scans, and plain abdominal films for all patients undergoing tube graft repair using the endovascular graft system (early prototype) between February 10, 1993, and January 24, 1995.**
Results: **Sixty-eight patients underwent placement or attempted placement of a tube graft implant in 13 centers in the United States. Nine patients required conversion to open repair, leaving 59 patients with functioning grafts for evaluation. The mean follow-up time was 27 ± 8 months (range, 2 to 48 months). Twenty-eight (47%) of 59 patients had initial periprosthetic leaks (6 proximal, 14 distal, 3 proximal and distal, 5 indeterminate) on their first postoperative CT scans. Fourteen (50%) of the initial 28 leaks sealed spontaneously. Two other patients had their leaks sealed by endovascular means, leaving 12 patients with persistent leaks for follow-up evaluation. Four patients developed late leaks between 18 and 24 months of follow-up: one who had a spontaneously sealed initial leak, one with a second leak, and two who developed late leaks. Of the 16 patients with sealed leaks, 10 had aneurysm size reduction during follow-up. Three aneurysm sacs enlarged before spontaneous sealing but have not had sufficient follow-up time to document the size change since the seal. One patient died of respiratory failure 5 months after graft implantation. One patient whose leak was sealed by intervention has not yet had a CT scan for evaluation. In one patient with a sealed leak and whose aneurysm had initially shrunk, the area reopened and progressed to a nonfatal rupture that was surgically corrected. There were two late deaths from unrelated causes. Twelve patients in the sealed group are alive and well. Of the 12 patients with persistent leaks, five underwent open surgical repair without complication, and one underwent successful endovascular repair with a second graft. Six patients continue to live with their initial grafts and have an average aneurysm sac enlargement of 0.1 cm per year.**
Conclusions: **Although initial periprosthetic leaks were common with the use of this early prototype, 50% spontaneously sealed. The subsequent clinical course of patients with persistently sealed leaks was no different from that of patients who had no leaks. However, continued CT surveillance is warranted, because in one patient with an initially sealed leak, the area reopened and progressed to nonfatal rupture. Another two patients without initial leaks developed late leaks. In a small group of selected patients with continued leaks, their aneurysms appeared to enlarge at a rate considerably slower than would have been expected in patients with untreated aneurysm, suggesting that even a person after endovascular repair with a persistent leak may have had some beneficial hemodynamic modification. (J Vasc Surg 1998;27:606-13)**

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Endovascular repair of abdominal aortic aneurysm with a variety of devices is undergoing clinical investigation worldwide. One early and potentially adverse event after endovascular repair is periprosthetic leak. It results from an incomplete seal at an attachment site or backbleeding from patent lumbar or inferior mesenteric arteries. Periprosthetic leak has been observed in all types of devices used.[1-7] During the course of follow-up examination, some periprosthetic leaks spontaneously seal. There is a difference of opinion among the

investigators concerning the prognosis for patients who experience periprosthetic leak. Some investigators think that, if a periprosthetic leak occurs, even if it seals later, the patient is at risk for continued enlargement of the aneurysm and subsequent rupture.[5] Other investigators think that, if a leak seals, the clinical behavior of the aneurysm sac is similar to that after endovascular repair in the absence of a leak.[8]

The device developed by Endovascular Technologies (Menlo Park, Calif.) is undergoing evaluation in a multicenter trial approved and monitored by the Food and Drug Administration. The objective of this report is to evaluate the risk factors, natural history, and clinical consequences for patients who develop periprosthetic leak after transfemoral endovascular repair of an abdominal aortic aneurysm. The database from the early prototype tube graft was used to acquire the longest follow-up period for patients with periprosthetic leak.

MATERIALS AND METHODS

We were given access to files at Endovascular Technologies that included all initial and follow-up reports and the serial imaging studies for patients included in this study. Imaging studies included preoperative contrast-enhanced computed tomography (CT) scans, angiograms, and periodic postoperative CT scans, plain abdominal films, and color-flow duplex scans.

To provide the longest follow-up periods for patients who had periprosthetic leaks, the earliest prototype tube graft patient population was used, recognizing that the device has undergone modification and that the device being surveyed is no longer in clinical use. However, we think the affect of periprosthetic leak and subsequent clinical outcomes are germane for understanding all types of endoprostheses.

The data abstracted from the clinical records and recorded on a Microsoft Excel spreadsheet included age, gender, date of graft placement, length of hospital stay, graft diameter relative to proximal and distal neck sizes, concomitant anticoagulant or antiplatelet therapy, and medical institution. Subsequent endovascular and open procedures and the complications associated with additional procedures were reported. All radiographs were interpreted in consensus by both investigators. The preoperative angiograms were reviewed for contrast delineation of the inferior mesenteric artery, infrarenal lumbar arteries, and angulation of the infrarenal aorta of more than 45 degrees. Subsequent plain abdominal films were reviewed for evidence of attachment system fracture or graft migration. Preoperative contrast-enhanced CT scans of the proximal and distal necks where the attachment systems were to be placed were inspected for intraluminal thrombus and the degree of calcification. Calcification was divided into three subjective categories; none, moderate, and severe.

Postoperative CT scans, some performed with 10 mm slices, were examined for evidence of periprosthetic leak (i.e., endoleak), as defined by perigraft contrast enhancement between the outer lumen of the graft and the inner surface of the aneurysm wall. Proximal and distal leaks were identified and defined as any contrast enhancement, which extended into the aneurysm lumen adjacent to the respective attachment system. The leak was designated indeterminate if perigraft contrast was not in proximity to either attachment site but was in the aneurysm sac.

Aneurysm images were selected at the point of maximum diameter and were analyzed as previously described.[8] Briefly, the images were selected from comparable locations, digitized at 300 dpi, and cropped of identifying information. Blinded determination of best-fit ellipses was performed by computerized planimetry with calibration from accompanying scales (NIH image, V1.57). The major diameter was chosen to reflect aortic size because it is roughly equivalent to the most common clinically used measurement of maximum aneurysm diameter and because in previous studies changes in this parameter paralleled changes in aortic image area, perimeter, and minor diameter.

Chi square analyses were performed to assess relationships between the presence of a leak and discreet variables. Student's t tests were used to compare continuous parameters. A p value of less than 0.05 was selected for determination of statistical significance. Descriptive statistics are given as ±1 standard deviation.

RESULTS

From February 10, 1993, through January 24, 1995, 68 patients underwent placement or attempted placement of a tube graft implant at 13 centers participating in phase I and II trials in the United States (Appendix I). There were 62 male and 6 female patients between the ages of 69 to 88 years (mean, 73 ± 8 years). During the initial hospitalization, nine patients required conversion to open repair. Conversions occurred primarily on the operating table and were related to an inability to place the sheath or graft in the appropriate anatomic posi-

Table I. Explantation month and associated conditions

Explant patient and month	*Type of new graft*	*Conditions and postoperative diagnosis (month)*
A-5	Aortic	Leak (0), Coumadin
B-10	Aortobiiliac	Leak (0), migration (6), attachment system fracture (6)
C-12	Aortobifemoral	Leak (0), attachment system fracture (8), migration (8)
D-17	Aortoaortic	Attachment system fracture (6), migration (16), no leak
E-17	Aortoaortic	Leak (0), Coumadin, increasing AAA size (6)
F-25	Aortic	Leak (0), leak sealed (6), attachment system fracture (18), second leak (18), increasing AAA size (18), migration (24), rupture (25)
G-25	Endo-aortoiliac	Leak (0), attachment system fracture (18), increasing AAA size (18), migration (24)
H-30	Aortoaortic	Attachment system fracture (12), increasing AAA size (18), migration (24), leak (24)
I-32	Aortobiiliac	Leak (21), increasing AAA size (30), attachment system fracture (30), migration (30)
J-37	Aortoaortic	Leak (0), migration (12), increasing AAA size (24), attachment system fracture (25)

AAA, Abdominal aortic aneurysm.

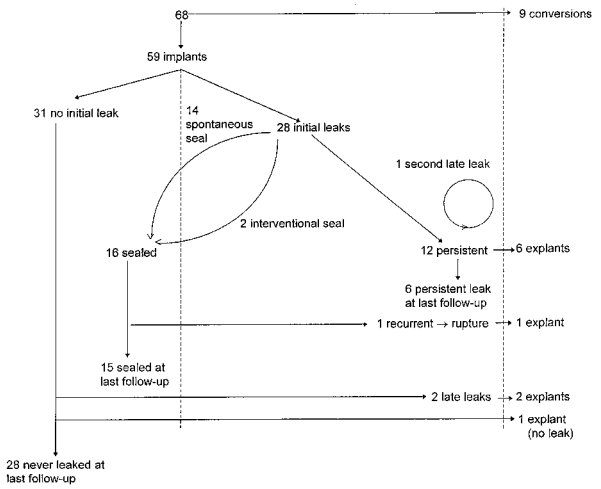

Fig. 1. The tree diagram illustrates the complex course of patients with unsealed and sealed leaks.

tion. Conversion to open repair was performed without major morbidity and mortality. All further data exclude the initial conversions, leaving 59 patients who were discharged from the hospital with functioning endovascular grafts. The preoperative major diameter of aneurysms ranged from 3.6 to 11.5 cm, with a mean size of 5.24 ± 0.63 cm (size grade: 15 = S, 39 = M, 5 = L).[9] The mean hospital stay was 3.4 ± 2.3 days. Comparison of the length of stay with total institutional experience revealed that the three institutions that had completed six or more implantations had a length of stay of 2.7 ± 2.3 days, compared with 4.0 ± 2.1 days for those with fewer than six cases ($p = 0.022$). The mean follow-up period at the time of acquiring these data was 27 ± 8 months (range, 2 to 48 months).

During the period of follow-up, there were five deaths that were not related to the device or operation. Ten patients underwent explantation of their devices at the discretion of the managing clinical investigator. The associated conditions for explantation are summarized in Table I.

Twenty-eight (47%) of the 59 patients with successful endovascular grafts had initial leaks detected on their first postoperative CT scans (technical success, the graft was inplanted and functioning, of 53%). The locations for periprosthetic leak included the proximal attachment site in six, the distal attachment site in 14, and the proximal and distal attachment sites in three patients. Five patients had periprosthetic leaks of indeterminate origin, probably representing backbleeding from a lumbar or an inferior mesenteric artery, although thin-cut CT was not always available. There was no significant difference in the incidence of leaks between the first half of the study (43%) and the second half of the study (52%) ($p = 0.519$). There is no difference between an individual institution's first-half experience in the incidence of endoleak (50%) and the second-half experience (45%) ($p = 0.691$).

Of the 28 patients who demonstrated endoleak, 14 (50%) had leaks that spontaneously sealed (Fig. 1). Twelve of the 14 occurred within the first year of follow-up, and two occurred during the second year. The location of leaks that sealed included three proximal, seven distal, three indeterminate, and one proximal and distal leaks. There was no significant relationship between leak location and subsequent spontaneous closure. Two other patients underwent successful intervention to seal their leaks: one after

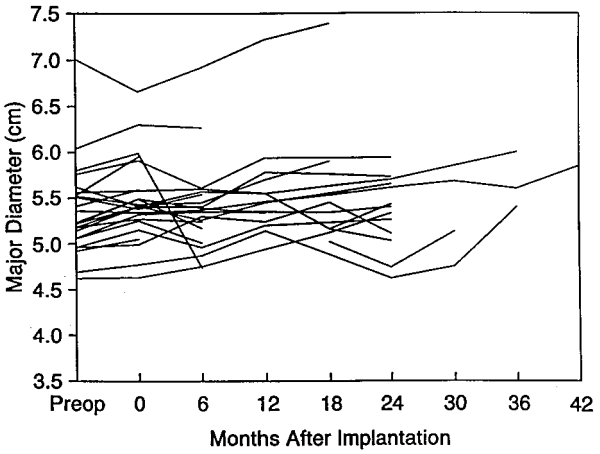

Fig. 2. Major diameters of all aneurysms with leaks are plotted between times when a leak was present, including the intervals adjacent to when a leak was not detected by computed tomography. A reduction in size frequently occurs in the last period because of leak cessation early in the interval. The largest aneurysm is off the scale of this graft; it enlarged from 11.51 to 11.96 cm between implantation and the 5-month follow-up assessment.

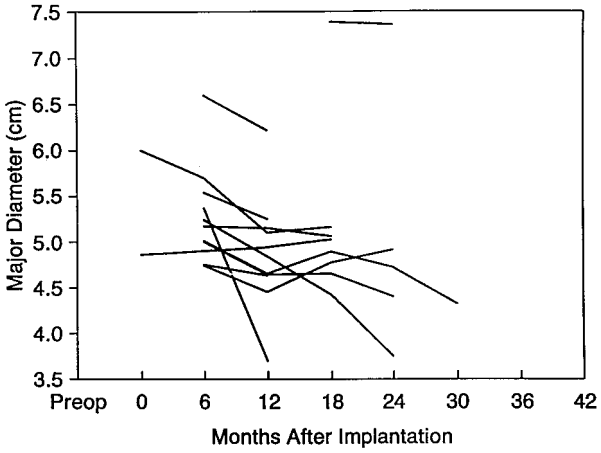

Fig. 3. Major diameters of individual aneurysms with leaks that ceased spontaneously or because of treatment. Only intervals between computed tomography scans with no leaks are depicted. Sealing of leaks was associated with reversal of aneurysm enlargement in all but two cases. One patient with marked aneurysm enlargement was found to have a leak months after enlargement could be detected, illustrating the importance of lifetime monitoring of aneurysm size and thorough investigation of enlarging aneurysms.

iliac kissing balloon angioplasty and stenting at 12 months followed by embolization of a persistently patent lumbar artery through the feeding ipsilateral hypogastric artery collateral at 17 months and the other after coil embolization of a proximal leak at 38 months. A total of 16 patients had initial leaks that were sealed.

Four patients (7%) developed late leaks. This occurred in one patient who had an initial leak that spontaneously sealed and subsequently reopened; one who had an initial, persisting leak with a second leak identified; and two who did not have initial leaks but developed late leaks. The late leaks were diagnosed between 18 and 24 months after initial implantation. The locations were the distal attachment system in three and proximal attachment system in one patient. None of these late leaks underwent spontaneous closure.

Figs. 2 and 3 depict the individual changes in the major diameters of aneurysms during periods bordered by a CT scan demonstrating a leak and during periods of no leak, respectively. In examining the changes in aneurysm diameter of the 16 patients with sealed leaks, one (Table I, explant F) demonstrated early aneurysm size reduction, and then the leak recurred with subsequent aneurysm enlargement that progressed to a nonfatal rupture of the abdominal aortic aneurysm, which was treated by open repair (Fig. 4). One patient had a very large aneurysm that continued to grow. This patient was initially treated on a compassionate use basis because of severe chronic obstructive pulmonary disease. He died 5 months after implantation, presumably of respiratory insufficiency. However, no autopsy was obtained, and rupture cannot be excluded. Both of these patients had short distal necks (neck grade II) and probably would not be treated with tube grafts today. Nine other aneurysm sacs had shrunk in size at the latest follow-up examination. Two of the nine patients died of causes unrelated to their aneurysm; heart disease and pneumonia occurred more than 20 months after sealing their leaks. Three aneurysm sacs enlarged before leak sealing. Enlargement ranged from 0.02 to 0.11 cm. These enlargements occurred when the leak was present. However, no CT scans are available to document size changes after sealing the leaks.

Two patients had leaks that were sealed with additional late interventions. One has not had CT scan measurement during the interval between sealing of the leak and this data analysis. The other patient has had aneurysm size reduction in the first complete interval after leak cessation.

Of the 12 patients with persistent leaks, four underwent attempts at closure with balloon angioplasty and three with embolization. None of these

Fig. 4. Computed tomography (CT) scans from an area of maximum aneurysm size demonstrate enlargement of the aneurysm sac immediately after *(left)*, 18 months after *(middle)*, and 24 months after graft placement *(right)*. The recurrent endoleak is visible only on thin-cut CT images of the distal neck and is not seen on these aortic images.

were successful. Five patients (Table I, explants A, B, C, E, and J) underwent graft explantation without major morbidity and mortality, including one patient who did well for the next 8 months but subsequently died of heart disease. A sixth patient (Table I, explant G) had treatment with an aortoiliac endovascular graft. The major diameter change of the aneurysm before explantation in these patients was 0.03 cm shrinkage at 6 months, no change at 6 months, 0.47 cm enlargement at 18 months, 0.12 growth at 24 months, and 0.59 enlargement at 36 months.

Six patients have not had operations. One patient moved overseas and was lost to follow-up 2 months after implantation. The others had CT scans that demonstrated aneurysm enlargement of 0.08 cm, 0.24 cm, and 0.33 cm through the first 24 months. One patient showed aneurysm shrinkage of 0.55 cm after 24 months; the location of this patient's initial leak was indeterminate until 18 months, when a second proximal leak was diagnosed with a delayed-infusion CT scan. The sixth patient died of malignancy 45 months after graft implantation with an aneurysm that had enlarged 0.63 cm over 42 months. The average annual aneurysm major-diameter growth weighted for length of follow-up is 0.10 cm/year for all patients with persistent leaks.

The two patients with aneurysms with no initial leaks but with late-onset leaks had similar patterns of failure. Both (Table I, explants H and I) demonstrated an early decrease in size, but late hook fracture, tipping of the distal attachment system, distal leak, and subsequent aneurysm enlargement resulted in explantation.

Migration of the device attachment system was significantly associated with leak ($p = 0.013$); 8 (89%) of 9 patients with migration also had leaks. Of the 30 patients with leaks (initial, late, or both), 8 (27%) had migration, compared with an incidence of migration of 3.0% in patients without leaks. Several other potential risk factors for leak were found to have had no statistical significance, although nonsignificant trends were observed, including neck thrombus ($p = 0.086$), hook break ($p = 0.087$), and graft size less than either neck size ($p = 0.089$). Other parameters examined for potential associations with leak included anticoagulation ($p = 0.153$), inferior mesenteric artery patency ($p = 0.240$), neck calcification ($p = 0.599$), age ($p = 0.847$), neck angulation ($p = 0.943$), and gender ($p = 0.965$). We also examined the ratio of graft diameter to neck diameter in patients with and without leaks. The ratio for patients with leaks was 1.05 ± 0.12, and the ratio for those without leaks was 1.07 ± 0.12 ($p = 0.43$).

DISCUSSION

Since the original clinical report by Parodi in 1991, endovascular repair of abdominal aortic aneurysm is enjoying worldwide popularity.[10] A variety of techniques and devices have been proposed or are undergoing clinical evaluation. Despite enthusiasm for this less-invasive technique, it has yet to be proven that endovascular aneurysm repair is as durable or effective as conventional transabdominal aneurysm resection and grafting. There is no question that patient acceptance and reduced perioperative morbidity and mortality favor endovascular repair.[1] Nevertheless, some problems associated with endovascular repair, such as perigraft leak, may reduce the advantage of endovascular repair over conventional transabdominal surgical replacement.

Perigraft leak has been observed with the use of all available endovascular graft devices.[1-7] The incidence (47%) reported for Endovascular Technologies' initial experience with tube grafting may appear to be somewhat high. It is tempting to suggest that this high incidence associated with the initial experience may be part of the learning curve.[11]

However, the incidence remained the same for the first and second halves of the study experience and for the first and second halves of an individual institutional experience. We selected the first 68 patients undergoing tube graft implantation to provide the longest follow-up to define the clinical consequences of perigraft leak. The prototype used in this initial experience has undergone considerable modification and, presumably, improvement. The benefit of these changes is suggested by the current reduced incidence of perigraft leak. In the past 87 consecutive implants, 10 (11.5%) were found to have endoleaks as monitored by an independent core laboratory. Of these, 50% sealed spontaneously (personal communication with Victor Bernhard, MD: Endovascular Technologies Core Laboratory).

The reduced incidence with the newer devices may also represent better patient selection, although we were unable to identify any specific risk factor that would separate patients who had no perigraft leak after implantation from those who did. However, several factors showed a trend favoring an increased incidence of perigraft leak in the absence of statistical significance, possibly because of small sample size: thrombus at proposed attachment sites, mismatch of graft size to neck size, and attachment system fracture. However, since the initial identification of that complication, the attachment systems have been reengineered, and there have been no new instances of attachment system fracture in the newer devices. Statistical significance for the identified risk factors may be lacking despite a real etiologic relationship because the investigators might have learned from earlier leaks in the series and not selected patients with those risk factors for subsequent graft placements. This is no doubt true for patients with thrombus or severe calcification at proposed sites of attachment.

Earlier experience with endoleak using other devices suggested that the patients experiencing periprosthetic leaks remained at risk for aneurysm rupture, including those in whom the leaks were presumably sealed.[2,5,11] The experience gained with this series has demonstrated that patients who have persistent periprosthetic leaks continue to undergo expansion of their abdominal aortic aneurysms. However, in a selected group of observed patients (mean major diameter, 5.3 cm), the rate of expansion may be modified by an endovascular prosthesis. This is suggested by the average annualized aneurysm size increase of 0.10 cm/year and a maximum of 0.31 cm/year. In contrast, the estimated average annual size increase of an untreated abdominal aortic aneurysm is approximately 0.5 cm/year.[12] Using these figures, the anticipated aneurysm size increase over a 24-month interval should be about 1.0 cm. The presence of an endovascular graft therefore may modify the hemodynamics and reduce aneurysm size enlargement rates.

Patients free of endoleaks and those in whom the endoleaks were sealed and stayed sealed underwent progressive shrinkage of the major diameters of their abdominal aortic aneurysms. There was no behavioral difference between those two groups, and no patient in the no-leak group or in the persistently sealed-leak group experienced aneurysm rupture.

Periodic surveillance by contrast-enhanced CT scan must be carried out for all patients. One patient in the sealed-leak group had a site that reopened, with subsequent enlargement of his abdominal aortic aneurysm and progression to rupture. Two patients in the group without initial leaks developed late leaks with corresponding aneurysm enlargement. These findings suggest that some patients successfully treated by endovascular repair may fail later and that they remain at risk for late aneurysm rupture. Leaks that appear late may have a worse prognosis than early leaks; in this series, no late leaks spontaneously sealed. Teleologically, these leaks involve thrombolysis of previously thrombosed perigraft spaces, which may be biologically different from initial leaks. For this reason and until long-term data demonstrate the integrity of attachment sites and the precise incidence of late leaks, we suggest that all patients who have undergone successful endovascular repair of abdominal aortic aneurysms undergo periodic contrast-enhanced CT scanning at intervals of 6 to 12 months. Further value can be obtained from CT scans by including delayed images several minutes after the contrast infusion for visualization of slow-flowing prosthetic leaks. Careful monitoring of planimetry-derived aneurysm size changes may detect aneurysms destined for visualized leaks and aneurysm rupture. As learned with the patient imaged in Fig. 4, aneurysms that continue to enlarge must be carefully evaluated for occult or late leaks, and remedial action must be taken.

Patients with persistent or recurrent periprosthetic leaks should be considered for endovascular repair to control the leaks or for explantation and conversion to conventional transabdominal repair. Although these decisions must be individualized for the patient's health status and life expectancy, failure to respond to the presence or recurrence of a periprosthetic leak is associated with continued

aneurysm enlargement, and failure to address this issue places the patient at risk for aneurysm rupture.

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